

Development of the Human Dentition



Development of the **HUMAN** **DENTITION**



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Quintessence Publishing Co, Inc

Chicago, Berlin, Tokyo, London, Paris, Milan, Barcelona, Istanbul,
Moscow, New Delhi, Prague, São Paulo, Seoul, and Warsaw

First published as *Gebitsontwikkeling bij de mens*, in Dutch in 2015 by Bohn Stafleu van Loghum, The Netherlands.



Library of Congress Cataloging-in-Publication Data

Names: Linden, Frans P. G. M. van der, 1932- , author.
Title: Development of the human dentition / Frans P.G.M. van der Linden.
Other titles: Gebitsontwikkeling bij de mens. English
Description: Hanover Park, IL : Quintessence Publishing Co., Inc., [2016]
|
Translation of: Gebitsontwikkeling bij de mens / F.P.G.M. van der Linden.
Houten : Bohn Stafleu van Loghum, 2010. | Includes bibliographical references and index.
Identifiers: LCCN 2016005916 | ISBN 9780867157253
Subjects: | MESH: Dentition | Maxillofacial Development | Tooth--growth & development | Atlases
Classification: LCC QP88.6 | NLM WU 17 | DDC 611/.314--dc23
LC record available at <http://lcn.loc.gov/2016005916>



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Quintessence Publishing Co Inc
4350 Chandler Drive
Hanover Park, IL 60133
www.quintpub.com

5 4 3 2 1

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Editor: Bryn Grisham
Design/Production: Angelina Sanchez

Printed in the United States of America

Contents



Video Clips **vii**
Preface **ix**
About the Author **x**
Author's Note on Terminology **xi**

- 1** Formation of Teeth **1**
- 2** Jaw Growth During Formation and Eruption of Deciduous Teeth **11**
- 3** The First Transitional Period: Transition of Incisors and Emergence of First Permanent Molars **33**
- 4** Intertransitional Period **53**
- 5** The Second Transitional Period: Transition of Canines and Deciduous Molars/Premolars and Emergence of Second Permanent Molars **65**
- 6** Changes in the Molar Region **73**
- 7** The Adult Dentition **85**
- 8** General Aspects of the Development of the Dentition **95**



- 9** Growth and Development of the Facial Complex: Interactions Among the Dentition, Skeleton, and Function **109**
- 10** Abnormalities of the Dental Arches **129**
- 11** Class II, Division 1 Malocclusions **137**
- 12** Class II, Division 2 Malocclusions **145**
- 13** Class III Malocclusions **159**
- 14** Open Bites and Nonocclusions **169**
- 15** Asymmetries, Transverse Deviations, and Forced Bites **177**
- 16** Premature Loss of Deciduous Teeth **185**
- 17** Statistical Data **201**
- Index **217**

Video Clips



The contents of this book are accompanied by 50 video clips that are referenced throughout the book. These clips can be accessed at: www.youtube.com/quintbook

Clip	Title	Duration (min:sec)
1	Tooth Development	3:53
2	Formation of Mandibular Molar Crown	0:58
3	Formation of Mandibular Incisor	0:19
4	Formation of Mandibular Canine	0:19
5	Formation of Mandibular Molar	0:24
6	Formation of Mandibular Incisor, Canine and Molar	0:22
7	Eruption and Transition of Central Incisors with Surrounding Soft Tissues	0:20
8	Transition of Mandibular Incisors with Moderate Space	0:19
9	Transition of Maxillary Incisors with Moderate Space	0:12
10	Transition of Mandibular Incisors with Excess of Space	0:21
11	Transition of Maxillary Incisors with Excess of Space	0:18
12	Transition of Mandibular Incisors with Shortage of Space	0:20
13	Transition of Maxillary Incisors with Shortage of Space	0:21
14	Changes of Maxillary Permanent Incisors After Extraction of Deciduous Canines in Anterior Crowding	0:30
15	Transition of Mandibular and Maxillary Incisors with Moderate Space	0:20
16	Transition of Canines and Premolars with Excess of Space	0:15
17	Transition of Canines and Premolars with Moderate Space	0:16
18	Transition of Canines and Premolars with Shortage of Space	0:17
19	Eruption of Second Permanent Molars	0:15
20	Eruption of Third Permanent Molars	0:18
21	Movements of First Permanent Molars	0:20
22	Rail Mechanism	0:17
23	Eruption Rate and Reduction of Eruption by Force Application	1:43
24	Resorption of Deciduous Molar Associated with Eruption of Premolar	0:14
25	Rotating Overview of Developing Dentition	1:39
26	Cone-Funnel Mechanism	0:49
27	Diagnosing Anterior Forced Bite Component in Mild Class III Malocclusion	0:14
28	Normal Tooth Mobility	0:19
29	Excessive Tooth Mobility Caused by Periodontal Breakdown	0:17

Clip	Title	
30	Radiographic Movie of Swallowing	0:13
31	Eruption and Transition of Central Incisors in Severe Class II/1 with Anterior Soft Tissues and Lip-interposition	0:21
32	Lateral View of Development of Severe Class II/1 Malocclusion	0:51
33	Various Stages Between Normal Occlusion and Severe Class II/1 Malocclusion	0:15
34	Tipping of Central Incisors with Anterior Soft Tissues	0:15
35	Lateral View of Development of Class I Malocclusion with Symptoms of Class II/2 Type A	0:57
36	Over-eruption and Tipping of Central Incisors in Class II/2	0:15
37	Frontal View of Development of Class II/2 Type A	0:19
38	Lateral View of Development of Class II/2 Type B	0:48
39	Frontal View of Development of Class II/2 Type B	0:19
40	Lateral View of Tipping of Incisors in Class II/2 Type B	0:17
41	Lateral View of Development of Class II/2 Type C	0:52
42	Eruption and Transition of Central Incisors in Class III with Anterior Soft Tissues	0:20
43	Lateral View of Development of Mild Class III Malocclusion	0:34
44	Lateral View of Development of Severe Class III Malocclusion	0:34
45	Various Stages Between Mild and Severe Class III Malocclusions	0:21
46	Over-eruption and Tipping of Central Incisors in Class III	0:14
47	Anterior Forced Bite in Mild Class III Malocclusion	0:17
48	Assessing Maximal Distal Movement in Anterior Forced Bite	0:22
49	Assessing Tongue Position at Rest	1:00
50	Space Creation by Erupting Mandibular Second Premolar	0:16

Preface



Learning about the development of the dentition is an essential part of the education of dentists, orthodontists, pedodontists, and dental hygienists, nurses, and assistants. To be able to determine if development is deviant, one has to be familiar with the variations that lead to an optimal result. Indeed, normal development must be learned before deviations can be understood.

In a dental practice, one is often confronted with the complex aspects of the development of the dentition. These aspects are easier to understand when insight is gained into how certain processes work and why. Such an insight facilitates comprehension of the large diversity typically found in the development of the dentition. In addition, knowledge of interactions between the growth of the face and functions of the orofacial region is essential for understanding the development of the dentition.

This book deals with tooth formation, development of the deciduous dentition, the transition, the changeover to the permanent dentition, and the aging of the dentition. Much emphasis is paid to the relationship and reciprocal influence of the development of the dentition with the growth of the face and with functional factors. Subsequently, the development of orthodontic malocclusions is presented, followed by the effects of untimely loss of deciduous teeth.

For the composition of this book, the work *Development of the Dentition*—published in 1979 in Dutch, in 1983 in English, and subsequently in other languages—served as a model. The information that has become available since its publication is incorporated in this volume. However, new information in this field is scarce. For the last few decades, growth studies involving invasive methods such as radiographs are not allowed. At the same time, analysis of the development of the dentition on skulls has diminished as the export of skeletal material from the Asian countries that previously provided it has been banned. Nevertheless, the picture of the normal and deviating development of the dentition has become quite clear and rather complete. Furthermore, the development of the dentition has not changed over the years and will not do so in the future.

The need for a new edition arose partly from the desire to update the presentation of the information. Two-dimensional illustrations do not adequately represent the spatial conditions or the relationships among the permanent teeth and their predecessors. Furthermore, the relationship between the size of the teeth and the dimension of the surrounding bony structures is not clear, nor are the differences between the maxilla and mandible. To facilitate three-dimensional understanding, digital illustrations have been included, derived from the six-DVD series *Dynamics of Orthodontics*, which was produced by Quintessence under chief editorship of the author. Also derived from this DVD series are the 50 animated video clips that accompany the text and figures to illustrate the development of the dentition. In addition to many line drawings, a large number of photographs of skeletal material are incorporated from the volume *Development of the Human Dentition: An Atlas* (Harper & Row, 1976), co-authored by the author and Herman S. Duterloo.

Acknowledgments

The author was privileged to serve from 1962 until 1995 as the first professor and chair of the Department of Orthodontics of the Radboud University Nijmegen, where excellent conditions were provided to create high-quality education of dentists and orthodontists. Serving as a teacher was a fruitful learning experience, and the contact with students was a continuous source of inspiration and stimulation. In addition, ideal facilities were available for basic and applied research. A national grant made it possible to carry out the Nijmegen Growth Study, a mixed longitudinal study of 486 children, covering the period from 4 to 14 years of age. In addition, more than 100 skulls, which demonstrated the normal development of the dentition as well as the development of malocclusions, could be collected and analyzed. The information obtained from these two investigations served as an important resource for the contents of this book. The results of the University of Groningen School Study and The University of Michigan Elementary and Secondary School Growth Studies, in which the author was involved, also provided a wealth of information.

Several people have contributed to this edition. Drs H. S. Duterloo, J. C. Maltha, G. J. H. Schols, and M. G. Ackermans critically read the manuscript and provided suggestions for improvement. The photographs of the skull material were made by J. L. M. van de Kamp and H. A. W. Bongaerts. The thousands of dental casts of the Nijmegen Growth Study were made by or under the supervision of J. J. W. Siepermann and B. F. Bouwman. Most of the line drawings were made by hand 40 years ago by H. Reckers. More than 550 digital illustrations, derived from the series *Dynamics of Orthodontics*, were adapted by M. Mentz. The material for these illustrations was provided by A. Klebba and M. Hecklinger, who also put together the 50 incorporated animated video clips. M. J. Th. Cillessen-van Hoek took care of the manuscript, and Bryn Grisham edited the English book, while Angelina Sanchez was in charge of its design and production. The author greatly appreciates the professional input and pleasant and constructive cooperation of these individuals.

About the Author



Dr Frans P.G.M. van der Linden

Dr Frans P.G.M. van der Linden received his dental and orthodontic education at the University of Groningen, the Netherlands. In addition he studied orthodontics at the University of Vienna, Austria, and the University of Washington, in Seattle, Washington. From 1962 until 1995 he held the position of Professor and Chairman of Orthodontics at the Radboud University Nijmegen, the Netherlands. In 1969-1970 he served as the Netherlands Visiting Professor at The University of Michigan, in Ann Arbor, Michigan. In 1975 he became the first European to be certified by the American Board of Orthodontics.

Dr Van der Linden has a strong interest in education. He received a grant from the European Union to develop the curriculum with the chairpersons from 15 countries for a 3-year full-time postgraduate course in orthodontics; in 1992, this so-called Erasmus Programme became the international standard in the education of specialists in orthodontics.

Dr Van der Linden is particularly interested in incorporating basic and clinical research results in the theory and practice of orthodontics. He is an internationally recognized lecturer and has published more than 200 papers and a number of books.

His main contribution is a series of six textbooks on orthodontics and dentofacial orthopedics. In addition, a practice-oriented book, *Orthodontic Concepts and Strategies*, appeared in 2004. Furthermore, Dr Van der Linden has been Editor-in-Chief and main author of the *Dynamics of Orthodontics*, an international multimedia project that presents the basic aspects of the field of orthodontics in six languages.

Dr Van der Linden's long-lasting activities in research and teaching have been widely recognized, even outside the fields of dentistry and orthodontics. He is the first dentist to be elected, in 1992, to the Royal Netherlands Academy of Arts and Sciences, founded in 1808 and consisting of 220 prominent scientists from all fields of arts and sciences. Moreover, in 1993 he received the Professor Lammers Prize from the Faculty of Medical Sciences at the Radboud University Nijmegen for his outstanding contributions in education and teaching. In addition, he received the 1998 Louis Ada Jarabak Memorial International Orthodontic Teachers and Research Award from the American Association of Orthodontists Foundation.

Author's Note on Terminology



There is large variation in the way teeth are defined. Many authors do not systematically use the same sequence in specifying teeth. In addition, some make use of popular scientific, nonvaluable terms, such as *upper* instead of *maxillary*. The terms *upper* and *lower* should only be used for indicating lips, not teeth. Teeth are placed in a jaw, and thus, the jaw should be specified first. The second differentiation regards the side, *left* or *right*. Third comes the number of the tooth. Finally, *deciduous* and *permanent* should be directly connected with the tooth involved.

So, teeth should be indicated in a standard way that follows a systematic sequence of relevance:

1. Jaw: Maxillary/mandibular
2. Side: Left/right
3. Tooth number: First/second or central/lateral
4. Deciduous/permanent
5. Tooth

Indeed, preference is given to using the correct anatomical descriptions. Therefore, not *upper* or *lower*, but *maxillary* and *mandibular*. Not *cuspid* but *canine* (*cuspid* is also used for having a cusp). Not *bicuspid* but *premolar* (some premolars have 3 cusps). Not *wisdom tooth*, but *third molar*. Not *primary* but *deciduous* (there are no secondary teeth). *Deciduous* or *permanent* should be placed directly in front of the tooth type because that belongs together and is the most essential specification.

Some examples of the correct tooth terminology used in this book include, maxillary right central permanent incisor, mandibular left deciduous canine, maxillary right second deciduous molar, and mandibular left first permanent molar.



Formation of Teeth

Initial Stages of Formation

Teeth arise from the interaction of two germ layers, the ectoderm and the mesoderm. The ectodermal tissue provides the enamel, the mesodermal tissue the dentin.

The first local changes leading to the formation of teeth occur in the 6th week after conception. At that time, the oral cavity is formed and covered with a two-layer epithelium with still-undifferentiated mesenchyme underneath. Between the two layers lies the basal membrane, which facilitates the communication between the two types of tissue.

At the location of the future dental arches, the epithelium thickens, and the dental lamina develops. At every location where a tooth has to appear, the ectoderm of the dental lamina bulges into the mesenchyme. The initial shape of the crown is formed by local differences in mitotic activity (differential proliferation) of the epithelium and mesenchymal tissue. The basal membrane is situated at the future enamel-dentin border. The mesenchymal cells at the inner side of the basal membrane differentiate into odontoblasts; the epithelial cells on the outer side differentiate into ameloblasts. These cells deposit dentin and enamel on the basal membrane and form the crown. Subsequently, the odontoblasts build up the dentin of the root. At the external side of the root, cementum is deposited by cementoblasts, which are differentiated from mesenchymal cells (Fig 1-1).

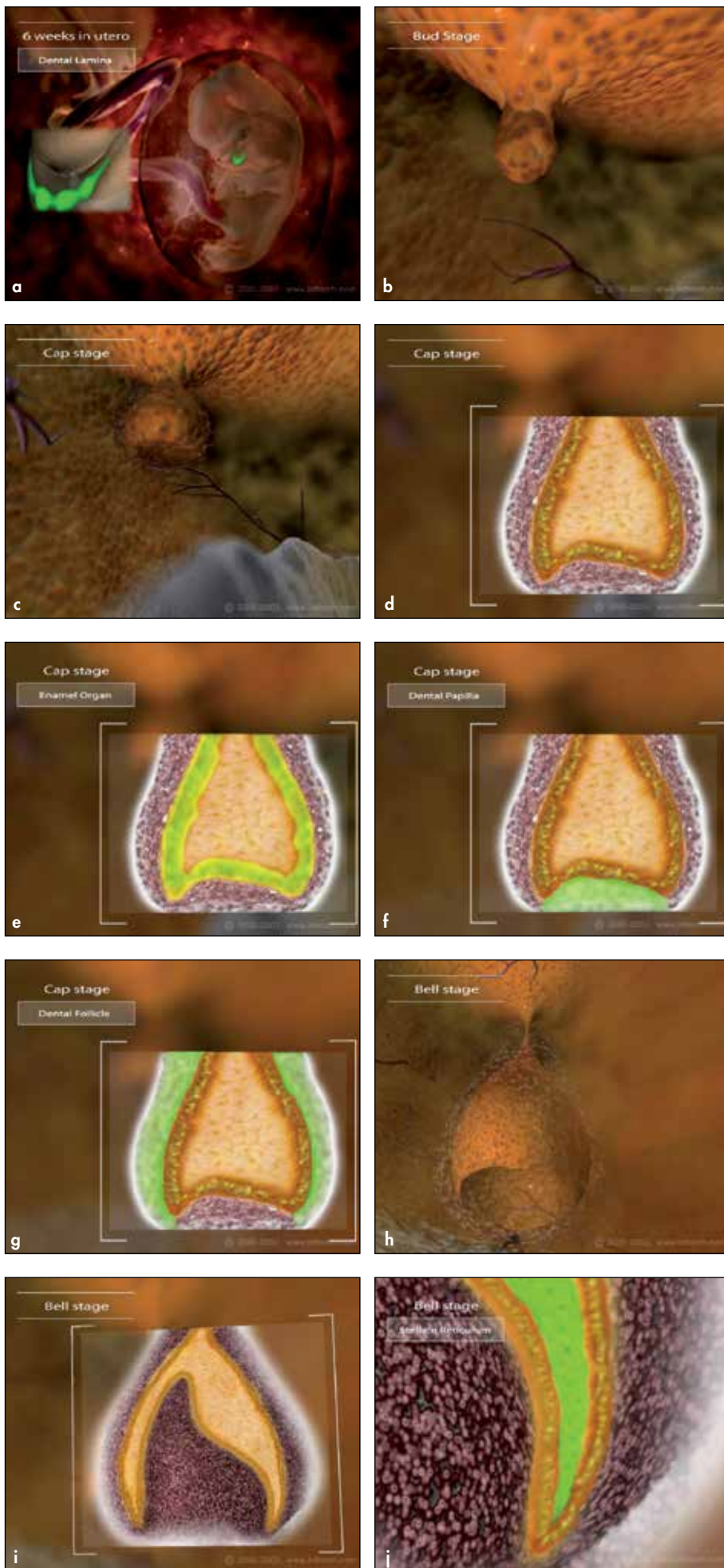
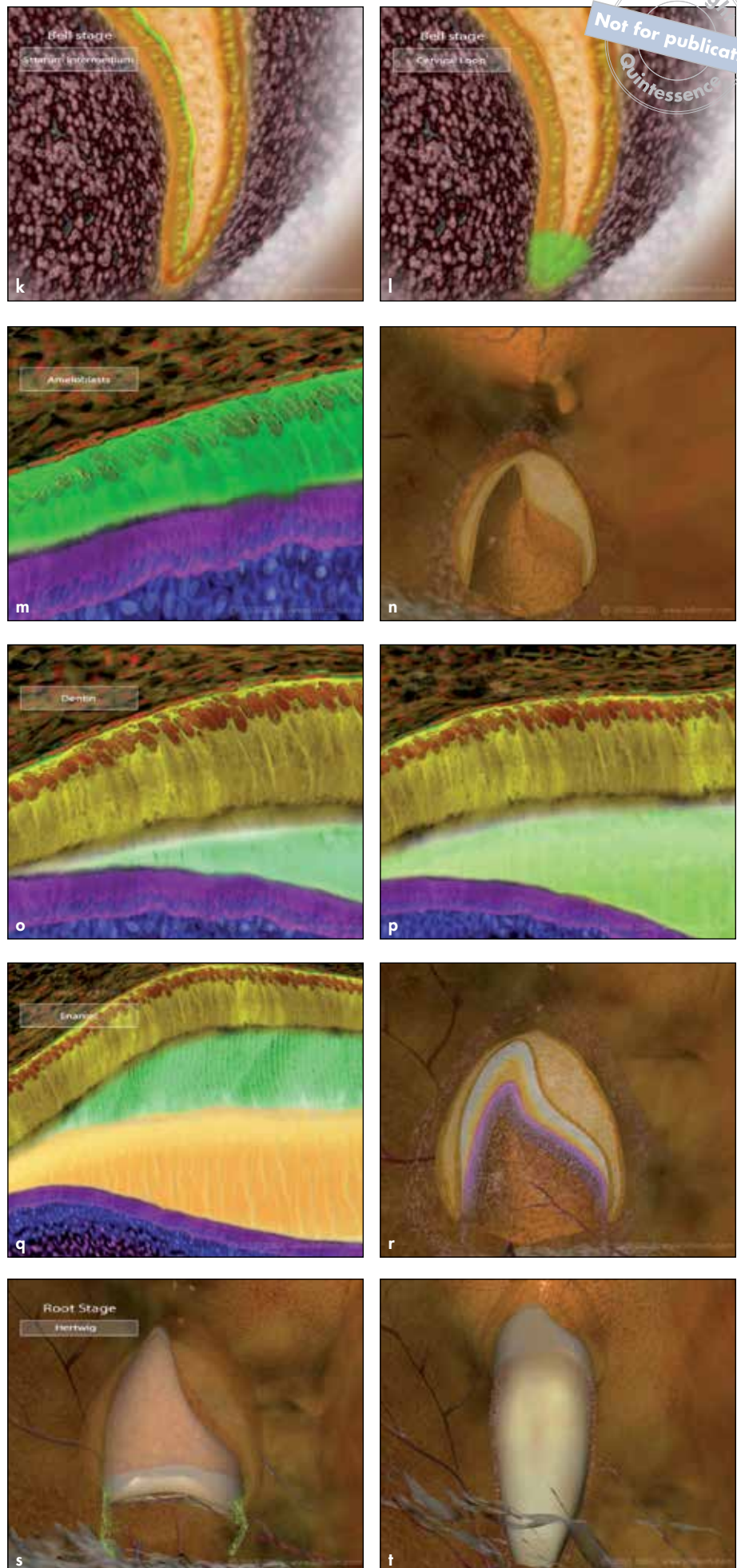


FIG 1-1 The formation of deciduous incisor. (a) In the 6 weeks in utero, the oral epithelium thickens by differential proliferation at the location where the dental arches will arise. The dental lamina is formed. (b) At every location where a tooth has to be formed, the ectodermal tissue bulges into the mesenchymal tissue of the dental lamina, resulting in a tooth bud. (c) Extended growth of the epithelium of the tooth bud by differential proliferation results in a cap. (d) The cap will partially enclose a cell-dense mass of mesenchymal cells. (e) At the inner lining of the epithelial cap, the cells become cylindrically shaped. These are the preameloblasts, the precursors of the cells that later will deposit enamel onto the basal membrane. (f) The external surface of the cap continues to consist of cuboidal cells. Within the cap tissue, the stellate reticulum, a loose structure of mesenchymal cells, is formed. The cells at the periphery of the cell-dense mesenchymal mass become arranged along the basal membrane and differentiate into preodontoblasts. These are the precursors of the cells that will deposit dentin at the basal membrane. (g) The remaining part of the dental papilla differentiates into the pulp. The mesenchymal cells around the cap form the dental follicle, which later will lead to the formation of the periodontal ligament. (h and i) The total structure has attained a bell form. (j) Preameloblasts and the reticulum stellatum.

FIG 1-1 (cont) (k) A separate cell layer, the stratum intermedium, arises between the preameloblasts and the stellate reticulum. (l) At the edge of the cap, where the external layer becomes the inner lining, a cervical loop is formed. (m) Prior to the deposition of enamel and dentin, the basal membrane together with the preameloblast and preodontoblast layers have attained the form of the future crown. (n) Then the crown stage starts. (o and p) The preodontoblasts differentiate into odontoblasts that deposit the first dentin at the basal membrane. (q) Shortly thereafter, the preameloblasts differentiate into ameloblasts and begin to deposit enamel at the already formed dentin. The dentin is deposited in the direction of the basal membrane. During that process the odontoblasts migrate in the direction of the pulp, leaving odontoblastic processes behind in the dentinal tubules. The ameloblasts deposit enamel also in the direction of the basal membrane, but do not leave processes behind. (r) The enamel deposition continues until the crown is completely formed. (s) After the crown is finished, root formation starts. The tissue of the cervical loop proliferates further in an apical direction and forms the epithelial stocking that is called the Hertwig root sheath. (t) Pulpal cells become arranged at the inner side of the Hertwig root sheath and differentiate to preodontoblasts and subsequently to odontoblasts, which will deposit the dentin of the root. With the outgrowth of the Hertwig root sheath, gaps appear in its cervical part. Mesenchymal cells of the tooth follicle migrate through these openings to the root surface. Thereafter they differentiate to precementoblasts and further to cementoblasts, which deposit cement against the dentin of the root. See video clip 1. (Printed from van der Linden et al¹ with permission.)



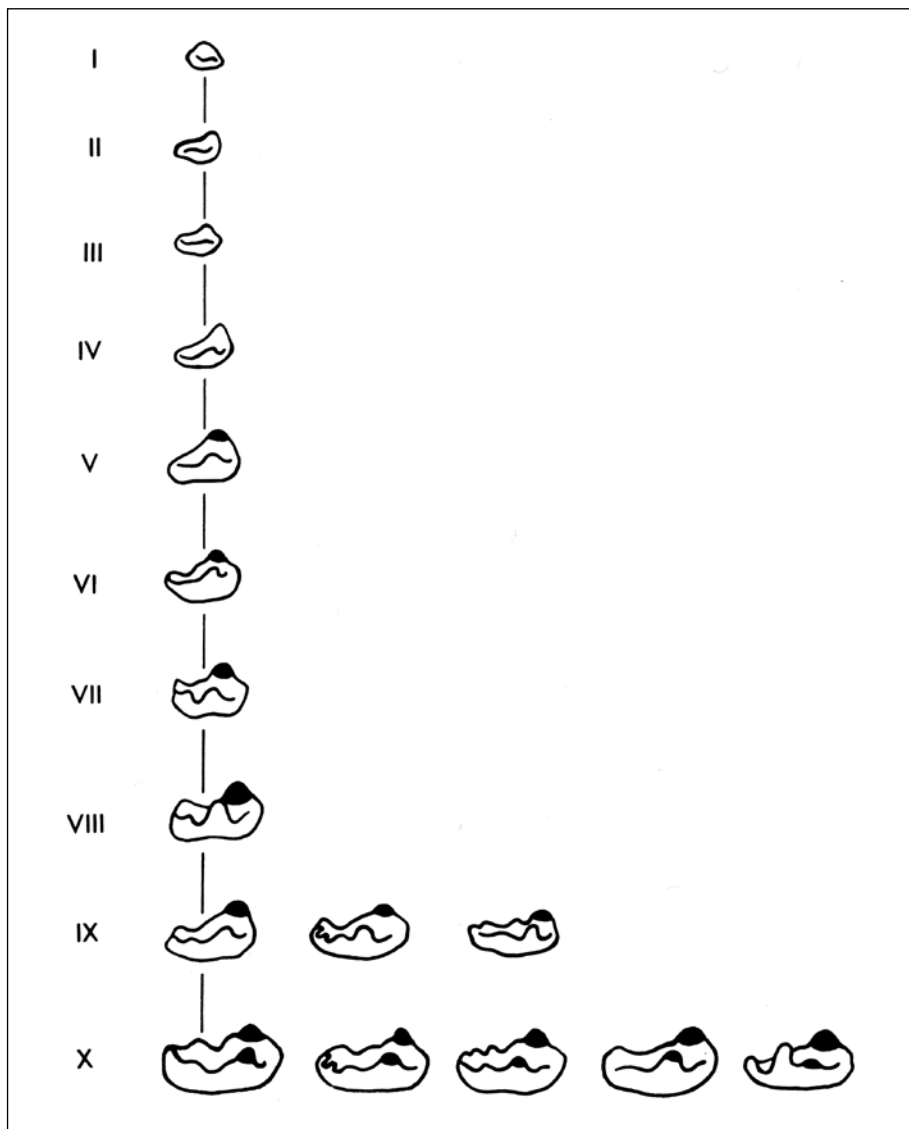


FIG 1-2 Development of the mandibular left first deciduous molar provided in morphodifferential stages. From the first macroscopic indication of the formation of the molar, growth and morphodifferentiation occur (stage I). Mineralization at the first point starts at stage V, at the second point at stage X. Between stages V and X, the size of the future tooth crown increases substantially. The distances between the cusp tips continue to enlarge. From stage IX onward, individual differences in morphodifferentiation occur, resulting in variations in the morphology of the completed crowns. (Reprinted from Kraus and Jordan² with permission.)

Morphogenesis of Teeth

The morphogenesis of incisors, canines, and molars is essentially the same. Only the timing and form vary.²

Forming molars gradually increase in size by interstitial growth of the inner enamel epithelium. Mineralization starts at one future cusp tip (Fig 1-2). In a genetically determined sequence, ameloblasts and odontoblasts differentiate at other future cusp tips, followed by mineralization. Areas that are not yet mineralized can still increase in size. After the mineralizing fields have become connected (ie, coalescence), the distance between the cusp tips involved cannot increase further. Enamel deposition continues in the valleys between the cusp tips and at the circumference of the crown. After the entire circumference of the occlusal part of the crown is mineralized, only deposition of enamel at the circumference of the crown contributes to the increase in the mesiodistal and buccolingual dimensions (Figs 1-3 and 1-4).

The mineralization of incisors starts almost simultaneously at three locations and spreads horizontally. The mineralization of molars starts at the future cusp tips, one after the other with some time in between, and spreads under a sharp angle with the occlusal surface. Consequently, compared with molars, incisors establish more of their mesiodistal crown dimension at a relatively early stage. Subsequently, they only become wider by approximal enamel deposition.

Fig 1-3 Changes in the morphology and the start and extension of the mineralization of a mandibular left second deciduous molar. All stages are presented at the same size, which obscures increases in dimensions (although they are comparable with those of the first deciduous molar in Fig 1-2). Mineralization of the second deciduous molar starts at stage X. In comparison with the first deciduous molar, morphodifferentiation has progressed considerably prior to the formation of predentin and enamel. At stage XV, the first coalescence takes place. At stage XVI, the mesial marginal ridge is established. At stage XVII, the distances between the distolingual, mesiolingual, and distobuccal cusp tips can still increase. At stage XVIII, the coalescence has progressed to the extent that the distances between the cusp tips cannot enlarge anymore. At stage XIX, the coalescence is established around the entire circumference of the occlusal part of the crown. At stage XX, the occlusal surface is fully mineralized. After stage XVIII, the circumference of the crown can increase only by apposition of enamel at its circumference. (Reprinted from Kraus and Jordan² with permission.)

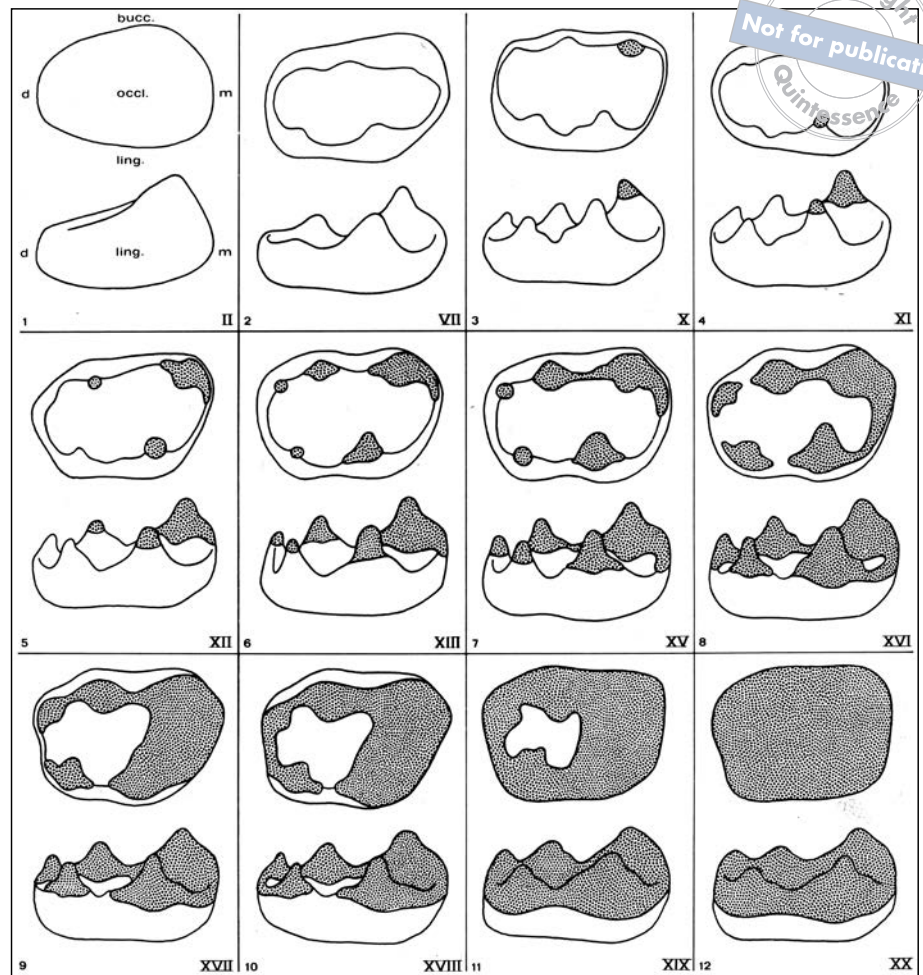
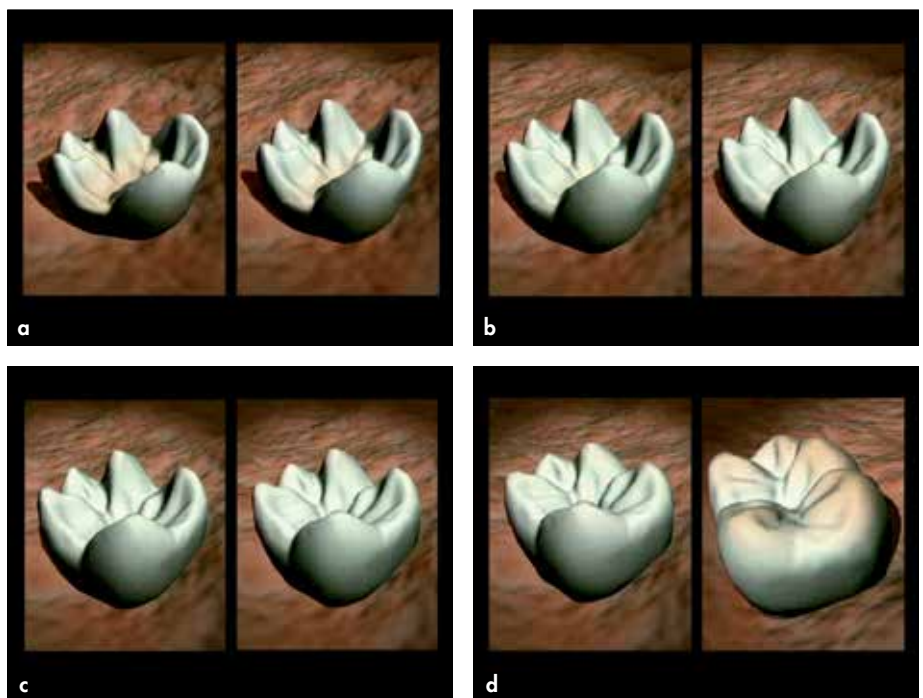


Fig 1-4 Formation of a mandibular first permanent molar observed from different directions. (a and b) Mineralization starts at the mesiobuccal cusp, followed successively by the other cusps. In the meantime, the slopes between the cusps become less steep. (c and d) Enamel is also deposited at the circumference of the crown, resulting in a slight increase in the mesiodistal and buccolingual dimensions. See video clip 2. (Printed from Van der Linden et al³ with permission.)



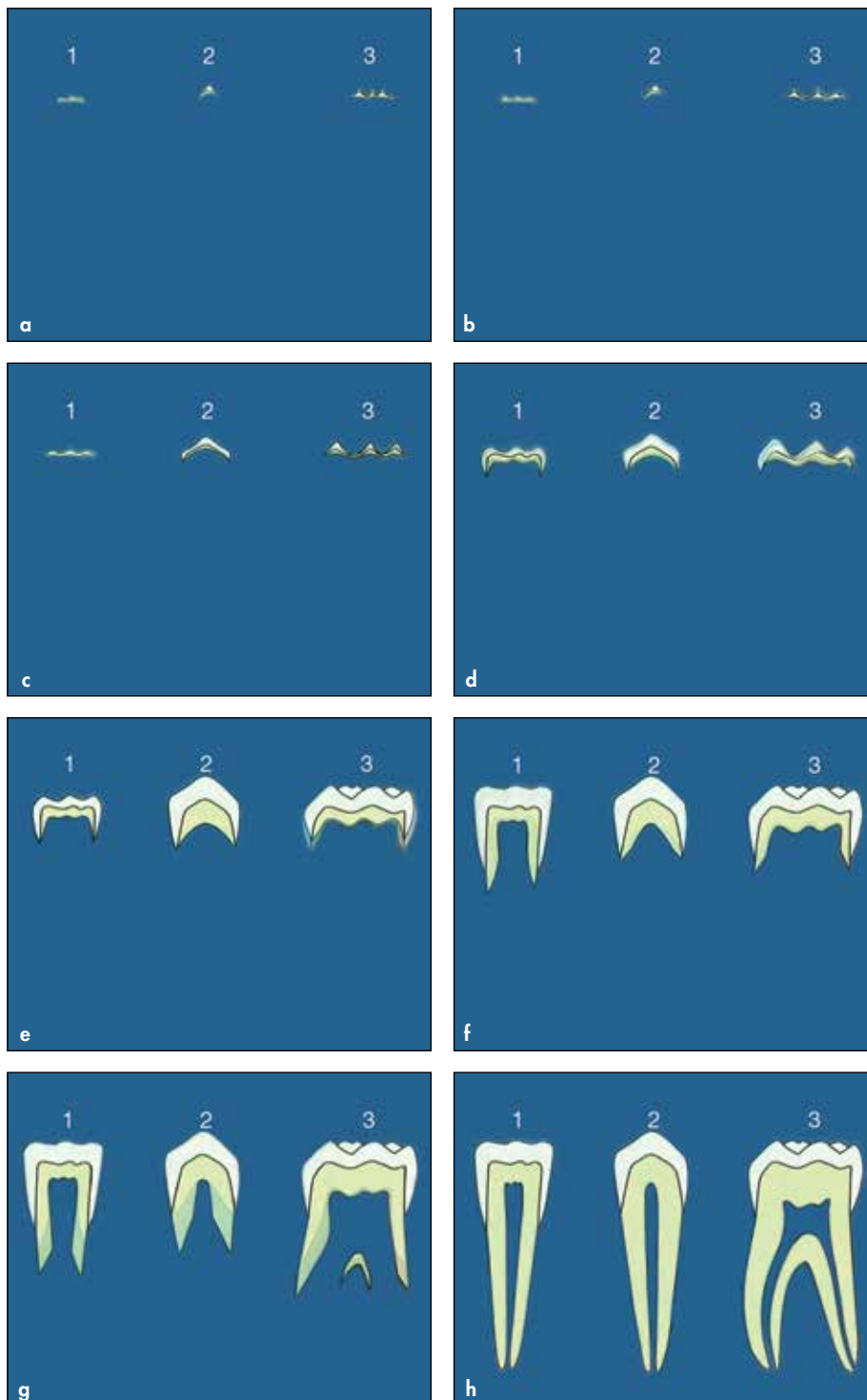


Fig 1-5 Formation of permanent teeth. (a and b) The mineralization of an incisor (1) starts at the middle of the incisal edge and shortly thereafter at two other locations more to the distal and mesial (the future mamelons). (c and d) The mineralization spreads parallel with the incisal edge, soon resulting in coalescence. (e and f) In that way, a substantial part of the mesiodistal crown dimension is realized early. (g and h) After the crown is completed, the root is formed. (a and b) The mineralization of a canine (2) starts at one point and spreads under an oblique angle. (c and d) A large part of its mesiodistal crown dimension is realized early. (e and f) A canine reaches the stage at which the width increase becomes limited to approximal enamel deposition later than an incisor does. The root formation starts. (g and h) The pulp cavity becomes smaller by dentin deposition at the pulp chamber and the inner surface of the root. (a and b) The mineralization of a molar (3) starts at the mesiobuccal cusp and some time later at the other cusps. (c and d) The occlusal dimension of the crown increases until overall coalescence is attained. (e and f) The slopes between the cusps become flattened by enamel deposition. The circumference of the crown increases somewhat. (g and h) In multirrooted teeth, the bi- or trifurcation appears. See video clips 3 to 6. (Printed from Van der Linden et al³ with permission.)

Mineralization of canines starts at a single point. Their morphodifferentiation and mineralization lag behind that of the incisors and molars. The mineralization of canines spreads under an angle of about 45 degrees with the long axis of the future tooth. The increase in mesiodistal crown width occurs more slowly in canines than in incisors. Due to the differences in crown formation, the mesial and distal demarcations of deciduous molars and canines are reached at about the same time, week 28 after conception; in incisors, this occurs in week 20 (Fig 1-5).

Fig 1-6 Comparison of the enlargement of three deciduous teeth expressed in millimeters and percentages of the final width. The mineralization of the maxillary incisor starts in the 16th week postconception (pc) and is somewhat earlier than that in the mandibular first molar. The mesiodistal dimension of the incisor tooth bud is at that time 3.5 mm, which is 54% of its ultimate size. The corresponding values for the molar are 2.8 mm and 34.5%. In week 20, the formation of the incisor has proceeded to the extent that increase in crown width can only be realized by approximal enamel deposition. The canine starts to mineralize in week 20. Regarding the mesiodistal dimensions, the values reached in week 20 for the incisor, canine, and molar, respectively, are 4.5 mm and 69%, 2.6 mm and 42%, and 4.3 mm and 53%. In week 24, the mineralization starts in the molar at the second point. In week 28, the first coalescence is attained, and the canine has extended to the mesial and distal sides. From that moment on, increase of its crown width is realized only by approximal enamel deposition. D, distal; M, mesial; IC, initial calcification; C, coalescence. (Data from Kraus and Jordan² and Van der Linden et al.⁴)

Development of some deciduous teeth						
Week pc	Maxillary central incisor		Maxillary canine		Mandibular first molar	
12	D	M			D	M
	1.2 mm	18.5%			1.0 mm	12.5%
16	IC		D	M	IC	
	3.5	54%	1.5 mm	22.5%	2.8	34.5%
20	IC		IC		IC	
	4.5	69%	2.6	42%	4.3	53%
24	IC		IC		IC	
	5.0	77%	3.8	61%	5.8	71%
28	IC		IC		C	
	5.5	85%	5.2	77.5%	6.7	82.5%
32	IC		IC		IC	
	6.0	92.5%	5.7	85%	7.4	91.5%
36	IC		IC		IC	
	6.5	100%	6.2	92.5%	7.9	97.5%

The increases in mesiodistal crown dimensions of a maxillary central incisor, maxillary canine, and mandibular first molar of the deciduous dentition are illustrated and compared numerically in Fig 1-6. Development of the incisor is clearly ahead of that of the two other teeth.

The mineralization of the mandibular deciduous teeth in five specimens at increasing developmental stages is presented in Fig 1-7. This figure also shows the relative sizes of the forming teeth within one specimen.

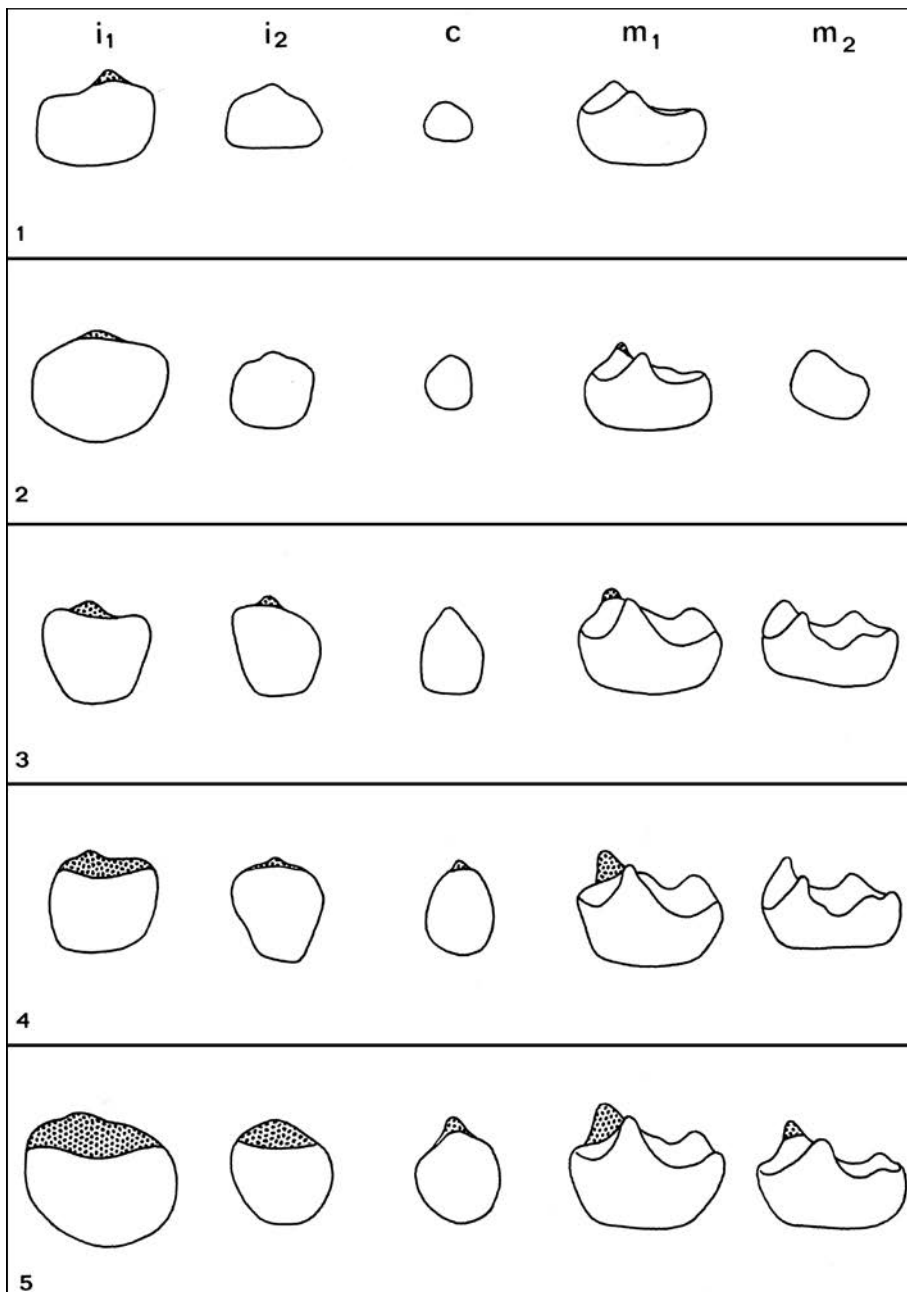


FIG 1-7 Mineralization of mandibular deciduous teeth. This figure is based on five specimens at successive levels of development. The central incisor (i_1) is the first tooth that starts to mineralize, followed by the mesiobuccal cusp of the first molar (m_1). Subsequently, mineralization begins in the lateral incisor (i_2), the canine (c), and the second molar (m_2). All five teeth are mineralizing prior to the appearance of the second mineralization point in the first molar. The differences in size of the tooth buds in the separate series go back to the differential increase of dimensions in the five teeth. In assessing the five series, one must realize that differences in the ultimate size of corresponding teeth would have come about if their development had not stopped. These differences are not related to the level of development but based on the fact that some children have larger teeth than others. (Reprinted from Kraus and Jordan² with permission.)

Basic Properties of Teeth



Teeth have some typical properties. They are composed of the hardest tissues of the body. That applies particularly to the enamel. In comparison with other tissues, enamel and dentin are formed very slowly. For example, the mineralization of the first permanent molar starts before birth. When it emerges at 6 years of age, its root is not yet completely formed.

Deciduous teeth are formed more quickly than permanent teeth. The first deciduous tooth emerges at 6 months of age, the first permanent one at 6 years. A deciduous incisor has only slightly more than 1 year for its formation, while a permanent incisor has almost 7 years (see chapter 17 for details).

In accordance with the differences in time of their formation, deciduous and permanent teeth differ in composition and particularly in the density of enamel. The mineralization level of deciduous teeth is lower than that of permanent ones.⁵ They have a whiter color (hence the name *milk teeth*), while permanent teeth have darker and yellower crowns. Because of the lower mineralization level, deciduous crowns are more susceptible to wear than are permanent ones. Deciduous molars lose their sharp cusp tips early.

In contrast to other tissues of the body, teeth cannot repair naturally. The parts of enamel and dentin lost by trauma or decay cannot be replaced. Enamel no longer can be deposited after the crown is completely formed. However, secondary dentin formation can continue on the pulpal side.

Tooth Positions During Development

Insight into the differences in the development of incisors, canines, and molars and of the deciduous and permanent teeth is essential for the understanding of the complex process of the development of the dentition. It is otherwise difficult to comprehend that deciduous and permanent incisors are formed in overlapping positions and that deciduous molars are formed one behind the other, without spatial limitations. On the other hand, second and third permanent molars are formed in a region where not enough space exists prior to the completion of jaw growth for them to be arranged one behind the other; therefore, they overlap.

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Page numbers followed by “f” indicate figures; those followed by “t” indicate tables; those followed by “b” indicate boxes

A

- Abrasion, 92
- Adolescent growth spurts, 11, 119, 119f, 164, 165f
- Adult dentition
 - description of, 88f, 89
 - elderly, 89, 91f–93f
- Agensis of permanent teeth, 129, 130f, 177, 179f, 214–215, 215t
- Alveolar bone, 21f, 48f, 91f
- Alveolar process, 29f, 73, 151f
- Alveoles, 121f
- Ameloblasts, 1, 3f
- Angle classification, of malocclusions, 137, 159, 177
- Ankylosis, 106, 132
- Anodontia, 129
- Anterior forced bite, 167, 168f, 182, 183f–184f
- Anterior open bite, 169–170, 172f
- Anterior section of apical area
 - anteroposterior relationship variations in, 115
 - in children, 115f
 - description of, 22, 24f, 25, 27
 - incisor transition in, 37f–39f, 37–38, 42–45, 42f–45f
 - large, 26f, 42, 42f–43f
 - in mandible, 22, 24f, 25
 - in maxilla, 27
 - medium, 24f, 37f–39f, 37–38, 50f
 - small, 25f, 27f, 69f
- Anterior teeth. *See also specific teeth.*
 - equilibrium in, 123f
 - mandibular
 - arrangement of, before emergence, 24f
 - overeruption of, 138, 142f
 - maxillary, 26f
- Apical area
 - anterior section of
 - anteroposterior relationship variations in, 115
 - in children, 115f
 - description of, 22, 24f, 25, 27
 - incisor transition in, 37f–39f, 37–38, 42–45, 42f–45f
 - large, 26f, 42, 42f–43f
 - medium, 24f, 37f–39f, 37–38, 50f
 - small, 25f, 27f, 69f
 - in mandible, 23
 - middle section of
 - in children, 115f
 - description of, 22
 - in intertransitional period, 66–68, 67f–68f
 - in mandible, 58f–59f, 59
 - mandibular teeth in relation to, 58f
 - in maxilla, 60f–61f, 61
 - variations in, 58f–61f, 59–61
 - posterior section of
 - in children, 115f
 - description of, 22
 - in mandible, 76f
 - in maxilla, 77f
 - size of, 76, 76f–77f
 - size variations in, 114, 114f
- Apical base, 22
- Arch length discrepancy, 129–132, 130f–132f
- Arch width, 95, 96f–99f, 207–208, 209t–211f
- Asymmetries
 - agenesis of permanent teeth as cause of, 179f
 - in dentition, 177, 178f
 - of face, 177, 215
 - in occlusion, 177, 178f
 - in open bite, 171f
 - in premature loss of deciduous teeth, 177, 179f
 - prevalence of, 215
- Attached gingiva, 103, 103f
- Attrition, 92

B

- Basal membrane, 1, 2f
- Body, growth of, 11, 12f
- Bone, 120f–122f, 120–122
- Bone remodeling, 122, 122f–123f
- Brodie syndrome, 181
- Bruxism, 92

C

- Canines
 - arch width at, 209t–210t
 - deciduous. *See* Deciduous canines.
 - mandibular, 58f, 67f, 209t–210t
 - maxillary, 63f, 65, 70f–71f, 209t–210t
 - mineralization of, 6, 6f
 - permanent
 - crowns of, 24f–26f, 33, 56, 70f

- deciduous canines versus, 65
 emergence of, 54, 65, 67f, 71f
 eruption of, 100
 formation of, 56f–57f
 impaction of, 132
 inclination of, 24f
 mesial angulation of, 58f
 position of, 21f
- Caries, 185
- Cartilage, 120, 122
- Cementoblasts, 1, 2f
- Cementoenamel junction, 26f
- Cementum, 1
- Central diastema, 41f
- Central incisors. *See also* Incisors.
 deciduous
 illustration of, 28f
 loss of, 35, 35f
 trauma effects on, 187
 maxillary, 38, 54, 55f, 64f, 103f, 147
 mineralization of, 8f
 permanent
 in Class II, division 2 malocclusions, 145, 149f
 distoincisor corners of, 26f–27f
 emergence of, 38, 41f, 43, 103f, 187
 eruption of, 35, 35f, 43–44
 incisal margins of, 22f
 in intertransitional period, 54
 lateral deciduous incisor loss with emergence of, 43
 mesioincisor corners of, 27f
 palatal tipping of, 153, 154f
 shortage of space effects on eruption of, 43–44
 size of, 55f
 transition of, 35, 35f–36f
- Centric relation, 179, 183f
- Chewing, 124
- Class I occlusion, 155, 155f, 173f
- Class II, division 1 malocclusion
 in anterior forced bite, 184f
 casts of, 40f–41f
 characteristics of, 137–143, 138f–144f
 Class II, division 2 malocclusion versus, 145, 146f, 147–148
 curve of Spee in, 139f
 in deciduous dentition, 138f
 deciduous molars/premolars in, 142f
 development of, 140f
 distocclusion, 143, 144f, 180f
 incisor development in, 141f
 in intertransitional period, 138f
 in lateral forced bite, 184f
 mandibular dental arch in, 138f–139f, 140, 143
 mandibular second deciduous molar premature loss with, 191
 maxillary buccal crossbite in, 181f
 maxillary incisors in, 40f, 137
 open bite in, 173
 in permanent dentition, 139f
 second deciduous molars in, 191
 secondary effects of, 144f
 severity of, 143f–144f
 total complete overbite secondary to in
 correction of, 156, 157f
- Class II, division 2 malocclusion
 central permanent incisors in, 149f, 154f
 characteristics of, 137, 145–151, 146f–151f
 Class II, division 1 malocclusion versus, 145, 146f, 147–148
 development of, 148f, 150f, 152f
 esthetic perception of, 156
 maxillary incisors in, 137, 145
 maxillary spatial conditions and, 153
 open bite in, 173
 predisposing factors for, 147f
 radiographs of, 150f
 severity of, 155
 stomion in, 145, 147f
 Type A, 145, 152f, 153, 155f, 156
 Type B, 145, 152f, 153, 156
 Type C, 145, 153, 153f, 156, 156f
- Class III malocclusions
 characteristics of, 159–166, 160f–167f
 in deciduous dentition, 159, 160f, 164
 deciduous molar premature loss in, 191, 197f
 description of, 137
 development of, 162f, 164f
 facial appearance associated with, 166, 167f
 forced bite associated with, 167, 167f–168f
 incisors in, 163f, 165f, 167f
 in intertransitional period, 159, 160f
 lower lip position in, 162, 163f
 mandibular dental arch in, 159
 maxillary palatal crossbite in, 179
 mesioclusion in, 164
 midface in, 161f
 negative overjet with, 190
 overjet in, 162
 in permanent teeth, 159, 161f
 prevalence of, 159
 pseudo, 167, 183f
 severity of, 165f
 tooth position in, 166
- Cleidocranial dysostosis, 106, 129
- Cone-funnel mechanism, 29f–30f, 30, 51f, 100, 109, 111f, 124, 172f
- Crossbite
 in children, 215
 palatal, 179, 180f–181f
- Cross-links, 105
- Crowding, 129, 130f, 151f, 215
- Crown
 of deciduous molars, 53, 65, 104
 of first permanent molars, 48f
 formation of, 1, 3f
 mesiodistal, 6–7, 206t, 207f
 of permanent canines, 24f–26f, 33, 56, 70f
 of premolars, 23f, 56f, 60f
 of third molars, 63, 64f, 74
- Curve of Spee, 96, 138, 139f



D

- Deciduous canines
 anatomy of, 46, 47f
 arch width changes after replacement of, 95
 eruption of, 17f
 extraction of, 100
 formation of, 13
 loss of, 65
 mesiodistal crown of, 63, 190, 206t, 207f
 permanent canines versus, 65
 premature loss of, 186f, 187f, 187–188, 189f
 wear of, 53
- Deciduous incisors
 anatomy of, 46, 47f
 central
 illustration of, 28f
 loss of, 35, 35f, 40f
 trauma effects on, 187
 crown widths of, 25
 development of, 7f
 eruption of, 100f
 formation of, 2f, 13
 gubernacular canal of, 46, 47f
 jaw growth and, 16
 lateral
 displacement of, 37f, 39
 illustration of, 17f, 40f
 position of, 24f
 premature loss of, 43, 61f, 187, 188f
 mandibular, 100f
 permanent incisors versus, 102
 position of, 23f
 premature loss of, 187–188, 187f–188f
 replacement of, 102f
- Deciduous molars
 ankylosis of, 132
 crown of, 53, 65, 104
 emergence of
 description of, 17f, 30
 molar field development before, 46
 first, 29f, 112f, 189
 furcation of, 62f
 jaw growth and, 13
 mineralization of, 4, 4f–5f, 9
 in occlusal contact, 30, 112
 position of, during development, 9
 premature loss of, 185, 188–191, 198f
 premolar proximity to, 104
 roots of, 18f
 second
 loss of, 35f, 97, 106
 mandibular, 33, 192f–193f, 195f
 maxillary, 189, 192f, 194f
 mesiodistal dimensions of, 34f
 migration of, 198b
 in occlusion, 30, 34f, 112f
 premature loss of, 188–189, 190f–197f, 198b, 198t
 premature resorption of, 185
 unilateral loss of, 190, 196f
 successors of, 83f
- Deciduous teeth. *See also specific teeth.*
 arch width changes after transition of, 96t
 cementum resorption, 102
 Class II, division 1 malocclusion in, 138f
 Class III malocclusion in, 159, 160f, 164
 composition of, 9
 crown widths of, 207, 207f
 dentin resorption, 102
 development of, 7f, 9, 15f, 29f
 early emergence of, 72
 emergence of, 9, 17f, 28f, 201, 202t, 203f
 eruption of, 9, 16, 72, 101
 first transitional period
 anatomical considerations, 46, 47f–50f
 incisor transition. *See* Incisors, transition of.
 overview of, 50, 50f–51f
 perioral tissues, 33–34, 34f–35f
 spatial conditions, 33–34, 34f–35f
 formation of, 201, 202f, 202t
 intertransitional period
 dentition arrangement in, 53, 54f, 55, 55f–57f, 62f, 63
 description of, 33
 mandibular teeth, 58f–59f
 maxillary teeth, 60f–61f
 root ends, 54
 tooth positions, 54
 wear effects, 53
 jaw growth and, 15, 15f
 migration of, 42, 186, 199, 199f
 mineralization of, 7, 8f
 occlusal plane of, 96
 overeruption of, 199
 premature loss of, 43, 46
 asymmetries in, 177, 179f
 canines, 186f, 187f, 187–188, 189f
 causes of, 185
 effects of, 186–198
 incisors, 187–188, 187f–188f
 lateral incisors, 43, 61f, 187, 188f
 migration after, 186
 molars, 185, 188–191, 198f
 root resorption as cause of, 185
 second molars, 188–189, 190f–197f, 198b, 198t
 roots of
 description of, 23
 premature resorption of, 185
 resorption of, 46, 54, 185
 second transitional period for
 in boys, 72
 description of, 33
 emergence sequence in, 65, 66f
 in girls, 72
 leeway space, 65–66
 timing of, 65
 terminal plane of, 34f, 55f, 97
 wear of, 92, 94f
- Dental age, 72
- Dental arches. *See also* Arch width.
 abnormalities in
 arch length discrepancy, 129–132, 130f–132f
 crowding, 129, 130f





- disturbed eruption, 106, 132, 133f
 - occlusion variations and deviations, 134, 135t
 - spacing issues, 129, 130f
 - tooth nonemergence, 106, 132, 133f
 - tooth position variations and deviations, 134, 134f, 135t
 - changes in, from deciduous teeth to permanent teeth, 97f
 - continuity of, 110f
 - in intertransitional period, 53, 97f–98f
 - mandibular
 - in Class II, division 1 malocclusion, 138f–139f, 140
 - in Class III malocclusions, 159
 - illustration of, 30f
 - maxillary, 30f
 - spatial conditions in, 186
 - Dental open bite, 174, 175f
 - Dentin
 - deposition of, 3f
 - formation of, 1, 2f
 - secondary, 9
 - Dentition. *See also* Teeth; *specific teeth*.
 - development of
 - arch width changes, 95, 96f–99f
 - occlusal plane, 96
 - in elderly, 89, 91f–93f
 - in intertransitional period, 53, 54f, 55, 55f–57f, 62f, 63
 - skeleton and, interactions between, 109, 114
 - in young adult, 88f, 89
 - Dentoalveolar compensatory mechanism, 115, 116f
 - Diastemata, 40f, 53, 187
 - Digit sucking, 124–125, 126f, 169
 - Distocclusion
 - in Class II, division 1 malocclusion, 143, 144f, 180f
 - in Class II, division 2 malocclusion, 155
 - Disturbed eruption, 106, 132, 133f
- E**
- Ectoderm, 1, 2f
 - Ectopic eruption, 106
 - Elderly
 - dentition in, 89, 91f–93f
 - skull in, 89, 91f–93f
 - Enamel deposition, 3f, 4
 - Endochondral ossification, 120
 - Extracellular matrix, 120f
 - Eye sockets, 11, 13f
- F**
- Face
 - asymmetries of, 177, 215
 - development of, 12, 14f
 - Facial complex
 - bone remodeling in, 122, 123f
 - development of
 - cone-funnel mechanism, 109, 111f
 - dentoalveolar compensatory mechanism, 115, 116f
 - interactions in, 109–116, 110f–116f
 - rail mechanism, 109, 111f
 - variations in timing of, 124
 - mouth breathing effects on, 124
 - orofacial functional factors that affect, 124–125, 125f–126f
 - swallowing effects on, 124, 125f
 - teeth position in, 122, 123f
 - Facial skeleton
 - in adolescents, 119, 119f
 - asymmetries in, 177
 - bone, 120f–122f, 120–122
 - in boys, 119, 119f
 - cartilage, 120, 122
 - functional components of, 117, 118f, 122, 124
 - in girls, 119, 119f
 - growth of, 117–123, 118f–123f
 - variations in, 119
 - vertical development of, 117, 118f
 - Fetus
 - eye sockets in, 11, 13f
 - facial development in, 12, 14f
 - jaw development in, 14f
 - mandible in, 14f
 - Final molar occlusion, 97
 - First permanent molars
 - arch width at, 209t–210t
 - crown of, 48f
 - emergence of, 35f, 198
 - anatomical considerations, 46, 49f–50f
 - description of, 33
 - in mandible, 48f
 - in maxilla, 49f
 - molar field development before, 46
 - overview of, 51f
 - space allocation for, 46, 48f–49f, 51f
 - mandibular, 48f
 - maxillary, 49f
 - occlusion of, 33, 34f, 46
 - position of, 113f
 - in young adults, 88f
 - First transitional period
 - anatomical considerations, 46, 47f–50f
 - incisor transition. *See* Incisors, transition of.
 - overview of, 50, 50f–51f
 - perioral tissues, 33–34, 34f–35f
 - spatial conditions, 33–34, 34f–35f
 - Forced bite, 167, 167f–168f, 179, 182–184
- G**
- Gingival line, 87
 - Growth
 - of body, 11, 12f
 - of head, 11–12, 12f–13f
 - of jaw, 13, 14f–23f
 - Gubernacular canals, 46, 47f–48f, 69
 - Gubernacular cord, 47f



H

Habitual occlusion, 182, 184f

Head

growth of, 11–12, 12f–13f

proportional change of, 11, 12f

Hertwig root sheath, 3f

I

Impacted teeth, 132, 133f

Incisors. *See also* Central incisors; Lateral incisors.

in Class II, division 1 malocclusion, 141f

in Class III malocclusions, 163f, 165f, 167f

deciduous. *See* Deciduous incisors.

displacement of, 122, 123f

formation of, 2f

inclination of, in second transitional period, 96

in intertransitional period, 55f, 62f

mineralization of, 4, 6f

occlusal contact of, 110f

permanent

anterior location of, 97f

crowding of, 215

crowns of, 20, 33

curve of Spee formation after emergence of, 96

deciduous incisors versus, 102

emergence of, 102f–103f

eruption of, 34, 37f, 100, 102f–103f

incisal edges of, 87

mandibular, 25, 42f

maxillary, 34, 35f

mineralization of, 126

position of, 21f

roots of, 85

tipping of, 165f, 166

transition of

anatomical considerations for, 35f, 46, 47f

asymmetric, 39, 40f–41f, 44

in large anterior section of apical area, 42, 42f–43f

in mandible, 38f, 42f, 50f

in maxilla, 39f, 50f

in medium anterior section of apical area, 37–38, 37f–39f

mode of, 37, 37f

overview of, 50, 50f

perioral soft tissues effect on, 33–34, 35f–36f

in small anterior section of apical area, 43–45, 44f–45f

spatial conditions effect on, 33–34

timeframe for, 35, 46

variations in position of, 122

Inter canine distance, 208f

Inter canine width, 95

Intercuspatation, 112, 112f, 114

Interdigitating sutures, 121, 121f

Intertransitional period

Class II, division 1 malocclusion in, 138f

Class III malocclusion in, 159, 160f

dental arch changes in, 97f–98f

dentition arrangement in, 53, 54f, 55, 55f–57f, 62f, 63

description of, 33

mandibular teeth, 58f–59f

maxillary teeth, 60f–61f

middle section of apical area in, 66–68, 67f–68f

permanent teeth emergence in

predecessors and, relationship between, 69

timing of, 72

root ends, 54

second permanent molar emergence in, 68, 70f–71f

tooth positions, 54

transition variations in, 67f

wear effects, 53

J

Jaw

apical area of, 22–27. *See also* Apical area.

contour of, 114f

growth of, 13, 14f–23f, 27, 28f

sagittal relation of, 13

transverse development of, 113, 113f

vertical changes in, 20

L

Lateral forced bite, 182, 182f–184f

Lateral incisors. *See also* Incisors.

deciduous

displacement of, 37f, 39

illustration of, 17f, 40f

position of, 24f

premature loss of, 43, 61f, 187, 188f

distoincisor corners of, 24f

mandibular, 38, 50f

maxillary

agenesis of, 214

ideal criteria for, 87

permanent, 34, 50f

premature loss of, 187

in severe crowding, 153

mineralization of, 8f

permanent

distoincisor corners of, 37

emergence of, 34, 38, 50f, 187

eruption of, 37, 37f

incisal margins of, 22f

labial divergence of, 153

mandibular, 37

maxillary, 34

position of, 23f

roots of, 23f

Leeway space, 65–66, 190

Long bones, 120, 120f

M

Malocclusions

Angle classification of, 137, 159, 177



- Class I, 137
- Class II, division 1. *See* Class II, division 1 malocclusion.
- Class II, division 2. *See* Class II, division 2 malocclusion.
- Class III. *See* Class III malocclusions.
- prevalence of, 215
- Mandible
 - anterior growth of, 164
 - apical area in, 23
 - middle section of, 58f–59f, 59
 - posterior section of, 76, 76f
 - condylar growth differences effect on, 118f, 119
 - cortex of, 89
 - emergence sequence in, 65
 - in fetus, 14f
 - first permanent molar emergence in, 48f
 - incisor transition in
 - illustration of, 38f, 42f, 50f
 - shortage of space effects on, 43
 - irregularities in, 109
 - morphology of, 11, 13f
 - in newborn, 13
- Mandibular canines, 58f, 67f, 209t–210t
- Mandibular condyles, 117, 118f
- Mandibular dental arch
 - in Class II, division 1 malocclusion, 138f–139f, 140
 - in Class III malocclusions, 159
 - illustration of, 30f
- Mandibular incisors, 42f, 109, 215
- Mandibular molars
 - impaction of, 75
 - second, 77, 78f
- Mandibular ramus, 73
- Mandibular symphysis
 - calcification of, 17f
 - in jaw development, 16
- Mandibular teeth. *See also specific teeth.*
 - anterior
 - arrangement of, before emergence, 24f
 - overeruption of, 138, 142f
 - anterior position of, 97
 - emergence sequence of, 65
 - in intertransitional period, 58f–59f
 - permanent, arrangement of, 86f
 - in young adult, 88f
- Maxilla
 - apical area in
 - middle section of, 60f–61f, 61
 - posterior section of, 76, 77f
 - first permanent molar emergence in, 49f
 - growth of, permanent molar development and, 75f
 - incisor transition in
 - illustration of, 39f, 50f
 - shortage of space effects on, 43–44
 - median suture in, 16
 - morphology of, 11, 13f
 - in newborn, 13
 - second molar formation in, 73
 - shortage of space in, 43–44
 - third molar formation in, 73
- Maxillary buccal crossbite, 181f
- Maxillary canines, 63f, 65, 70f–71f, 209t–210t
- Maxillary incisors
 - central, 38, 54, 55f, 64f, 103f, 147
 - in Class II, division 1 malocclusion, 137, 145
 - in Class II, division 2 malocclusion, 137
 - lateral
 - agenesis of, 214
 - ideal criteria for, 87
 - permanent, 34, 50f
 - premature loss of, 187
 - in severe crowding, 153
- Maxillary molars, 77, 79f–80f
- Maxillary premolars, 64f
- Maxillary teeth. *See also specific teeth.*
 - anterior, 26f
 - in intertransitional period, 60f–61f
 - mandibular posterior teeth and, 93f
 - permanent, arrangement of, 86f
 - in young adult, 88f
- Maxillary tuberosity, 73
- Mesenchymal cells, 1, 2f–3f
- Mesioclusion, 164
- Mesiodistal crown, 6–7, 206t, 207f
- Mesoderm, 1
- Milk teeth, 9
- Mineralization
 - of canines, 6, 6f
 - of deciduous teeth, 7, 8f
 - of incisors, 4, 6f
 - of molars, 4, 4f–5f, 9
- Molar fields, 46
- Molar occlusion, 207–208
- Molars, deciduous. *See* Deciduous molars.
- Molars, permanent
 - anterior eruption, 83
 - arch width at, 211t
 - deciduous molars versus, 104
 - development of
 - maxillary growth and, 75f
 - normal, 83f
 - space for, 73–75, 74f–75f
 - emergence of
 - first molars, 35f
 - panoramic radiographs of, 81f
 - second molars, 77, 78f, 80f–82f
 - third molars, 82f
 - final occlusion of, 97
 - first. *See* First permanent molars.
 - formation of, 4
 - mandibular
 - impaction of, 75
 - second, 77, 78f
 - maxillary, 77, 79f–80f
 - mesiopalatal cusp of, 190
 - posterior eruption, 83
 - posterior section of apical area size and, 76, 76f–77f
 - sagittal relationship of, 213t
 - second
 - angulation of, 74
 - emergence of, 77, 78f, 80f–82f
 - formation of, 73
 - mandibular, 77, 78f



maxillary, 74, 77, 79f–81f
 position of, 23f
 roots of, 56f, 85
 in young adults, 88f
 third
 agenesis of, 214
 angulation of, 74
 crowns of, 63, 64f, 74
 emergence of, 82f
 formation of, 9, 73
 mandibular, 75, 82f
 in occlusion maintenance, 112f
 tooth buds, 73–74
 Mouth breathing, 124

N

Natal teeth, 11
 Neonatal teeth, 11
 Neurocranium, 11, 12f, 18f
 Neuroclulsion
 development of, 154
 high lip position in, 154
 illustration of, 149f
 Newborn
 anterior teeth in, 14f, 15
 eye sockets in, 13f
 head growth in, 11, 12f
 natal teeth in, 11
 skull of, 13f, 18f
 Nijmegen Growth Study, 202, 208
 Nonocclusion
 in anterior region, 172, 174
 assessment of, 174
 causes of, 169
 characteristics of, 169
 detection of, 174f
 forms of, 170–172, 170f–172f
 illustration of, 170f
 incidence of, 173
 in posterior region, 172, 172f
 prevalence of, 173f
 radiographs of, 175f

O

Occlusal force, 109, 110f
 Occlusal plane, 96
 Occlusion
 asymmetries in, 177, 178f
 deciduous molars in, 30
 first permanent molars, 33, 34f, 46
 habitual, 182, 184f
 ideal, 86f
 intercuspatation's role in, 112, 112f
 second deciduous molars in, 30, 34f, 112f
 teeth emergence into, 27–30, 28f–30f, 114
 transverse, 179
 variations and deviations in, 134, 135t

Odontoblasts, 1, 3f
 Oligodontia, 129
 Open bite
 anterior, 169–170, 172f, 174
 assessment of, 174
 asymmetric, 171f
 causes of, 169
 characteristics of, 169
 dental, 174, 175f
 detection of, 174f
 digit sucking as cause of, 169, 171f
 forms of, 170–172, 170f–172f
 illustration of, 170f
 incidence of, 173
 incisor relationships in, 173f
 in malocclusions, 173, 173f
 posterior region affected by, 172f
 prevalence of, 173f
 radiographs of, 175f
 skeletal, 174, 176f
 tongue interposition as cause of, 169, 172f
 total, 170. *See also* Nonocclusion.
 variations in, 170f
 Osteoblasts, 120–121
 Osteoclasts, 120
 Overbite
 statistical data regarding, 207, 212t
 total complete. *See* Total complete overbite.
 Overjet, 154, 154f, 162, 180f, 207, 212t

P

Palatal crossbite, 179, 180f–181f
 Palatal mucosa, 103
 Parafunctional habits, 85, 92, 124
 Partial negative overjet, 154, 154f
 Periapical infections, 185
 Periodontal ligaments, 122
 Permanent teeth
 agenesis of, 129, 130f, 177, 179f, 214–215, 215t
 angulation of, 85, 87f, 214
 ankylosis of, 132
 anodontia, 129
 arrangement of, 85, 87, 87f, 90f
 attached gingiva, 103, 103f
 canines. *See* Canines, permanent.
 Class II, division 1 malocclusion in, 139f
 Class III malocclusion in, 159, 161f
 composition of, 9
 crowns of, 85
 development of, 9, 23f
 deviations in number of, 129
 in elderly, 89, 91f–93f
 emergence of
 in boys, 204f, 204t–205t
 definition of, 98
 description of, 72, 98
 eruption after, 98, 100–101, 101f, 104, 105f
 in girls, 202, 204f–204t
 statistical data regarding, 202, 203f, 204t–205t



variations in, 205t
 eruption of
 ankylosis effects on, 106
 cementum resorption associated with, 102, 102f
 direction of, 100, 124
 disturbed, 106, 132, 133f
 ectopic, 106
 after emergence, 98, 100–101, 101f, 104, 105f
 forces of, 104
 phases of, 98, 105
 postemergence phase of, 105
 potential for, 98
 pre-emergence phase of, 105
 primary failure of, 106
 process of, 99
 rate of, 106
 timing of, 101
 formation of, 203t
 functional factors that affect, 100
 ideal, 86f, 87
 impaction of, 132, 133f
 incisors. *See* Incisors, permanent.
 inclination of, 85, 87f, 214
 length determinants for, 87
 life span alterations in, 97
 molars. *See* Molars, permanent.
 oligodontia, 129
 parafunctional habits that affect, 85, 92
 position of, 85, 86f–87f
 retention of, 132, 133f
 root formation of, 57f, 101
 rotation of, before emergence, 23
 soft tissue effects on, 85
 stages of, 203t
 wear of, 92, 94f
 in young adult, 88f, 89
 Piriform aperture, 11, 26f–27f
 Preameloblasts, 2f
 Precementoblasts, 3f
 Premature loss
 of deciduous teeth, 43, 46
 asymmetries in, 177, 179f
 canines, 186f, 187f, 187–188, 189f
 causes of, 185
 effects of, 186–198
 incisors, 187–188, 187f–188f
 lateral incisors, 43, 61f, 187, 188f
 migration after, 186
 molars, 185, 188–191, 198f
 root resorption as cause of, 185
 second molars, 188–189, 190f–197f, 198b, 198t
 of maxillary lateral incisors, 187
 Premolars
 crowns of, 23f, 56f, 60f
 emergence of, 65, 69
 eruption of, 101
 mandibular
 agenesis of, 214
 formation stages of, 203f
 in second transitional period, 65
 maxillary, 64f

emergence of, 70f
 in second transitional period, 65
 proximity of, to deciduous molars, 104
 second, 59f–60f, 189
 in second transitional period, 65, 69
 Preodontoblasts, 3f
 Primary crowding, 129
 Primary failure of eruption, 106
 Pseudo Class III malocclusions, 167, 183f
 Puberty, 11
 Pulpal cells, 3f

R

Rail mechanism, 109, 111f, 124, 172, 172f
 Remodeling of bone, 122, 122f–123f

S

Second permanent molars
 angulation of, 74
 emergence of, 65, 66f, 68, 70f–71f, 77, 78f, 80f–82f
 formation of, 9, 73
 mandibular, 77, 78f
 maxillary, 74, 77, 79f–81f
 in occlusion maintenance, 112
 roots of, 56f, 85
 in young adults, 88f
 Second premolars, 59f–60f, 189
 Second transitional period
 in boys, 72
 description of, 33
 emergence sequence in, 65, 66f
 in girls, 72
 incisor inclination in, 96
 leeway space, 65–66
 timing of, 65
 Secondary crowding, 129
 Secondary dentin, 9
 Sexual maturity age, 72
 Skeletal age, 72
 Skeletal open bite, 174, 176f
 Skeleton
 dentition and, interactions between, 109, 114
 growth of, 120
 Skull
 asymmetries of, 177
 of child, 20f–23f
 of newborn, 13f, 18f
 teeth orientation based on, 18f–19f
 Spheno-occipital synchondrosis, 122
 Splanchnocranium, 11–12
 Stomion, 145, 147f
 Stratum intermedium, 3f
 Supernumerary teeth, 129, 131f, 133f
 Sutures, 121, 121f
 Swallowing, 124, 125f
 Synchondroses, 120

T

- Teeth. *See also specific teeth.*
 composition of, 9
 deciduous. *See* Deciduous teeth.
 development of, 16, 16f–17f
 emergence of, into occlusion, 27–30, 28f–30f
 formation of, 1–9
 impaction of, 132, 133f
 morphogenesis of, 4f–5f, 4–7
 natal, 11
 neonatal, 11
 permanent. *See* Permanent teeth.
 positions of
 asymmetries in, 177
 in Class III malocclusions, 166
 during development, 9, 15f
 digit sucking effects on, 124–125, 126f
 orofacial factors that affect, 124
 variations and deviations in, 134, 134f, 135t
 properties of, 9
 retained, 132, 133f
 rotation of, 134f
 size and shape of, deviations in, 129
 spatial orientation of
 in child's skull, 20f–23f
 in newborn skull, 18f–19f
 supernumerary, 129, 131f, 133f
 Telescoping bite, 179, 181f
 Terminal plane of deciduous teeth, 34f, 55f, 97
 Tertiary crowding, 129
 Third molars
 agenesis of, 214
 angulation of, 74
 crowns of, 63, 64f, 74
 emergence of, 82f, 85
 formation of, 9, 73
 mandibular, 75, 82f
 in occlusion maintenance, 112f

Tongue

- interposition of, open bite caused by, 169, 172f
 musculature of, 186

Tooth buds

- jaw morphology and, 29f
 maxilla and mandible morphology determined by, 11, 13f
 permanent molars, 73–74

Tooth size discrepancy, 132, 132f**Tooth wear**

- of deciduous canines, 53
 of deciduous teeth, 92, 94f
 of permanent teeth, 92, 94f
 terminology associated with, 92

Total complete overbite

- definition of, 145
 malocclusions with, 154
 mandibular crowding in, 151, 151f
 after orthodontic treatment, 156, 157f
 partial negative overjet and, 154, 154f

Transverse development of jaw, 113, 113f**Transverse deviations, 179, 180f–181f**

TSD. *See* Tooth size discrepancy.

U

“Ugly duckling” stage, 54

W

Wear. *See* Tooth wear.

Y

Young adult, dentition in, 88f, 89

